Data-Driven Demand Learning and Dynamic Pricing Strategies in Competitive Markets

Customer Behavior

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Hasso Plattner Institute (EPIC)

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Outline

- Goals of today’s meeting: Customer Behavior
- How to model customer choice: First approaches
- Exercise I: Simulation of Customer Decisions
- Exercise II: Simulation of Pricing Adjustments
Motivation

- Big picture: Modelling dynamic pricing competition
- Separable components: Customers, Markets, Merchants
- How to describe Customer Behavior?
- We look for a general model which is simple yet reasonable
- How do you decide?
Example: Buying Books on Amazon

<table>
<thead>
<tr>
<th>Preis + Versand (inkl. US)</th>
<th>Zustand</th>
<th>Verkäufer-Information</th>
<th>Lieferung</th>
</tr>
</thead>
</table>
| EUR 44,90                 | Gebraucht - Akzeptabel | Verkäufer: ialvamani  
100% positiv, (4 alle Bewertungen)  
Verkäuferinformationen, Impressum, AGB, Widerrufsrecht | Ankunft zwischen April 26 - Mai 2, Versandtarife |
| EUR 45,00                 | Gebraucht - Sehr gut | Verkäufer: lange_und_springer_antiquariat  
98% positiv in den letzten 12 Monaten. (28584 Bewertungen insgesamt)  
Verkäuferinformationen, Impressum, AGB, Widerrufsrecht | Ankunft zwischen April 27 - Mai 2, Versand aus Deutschland, Versandtarife |
| EUR 65,60                 | Gebraucht - Wie neu | Verkäufer: Totalbookstore  
98% positiv in den letzten 12 Monaten. (409 Bewertungen insgesamt)  
Verkäuferinformationen, Impressum, AGB, Widerrufsrecht | Ankunft zwischen Mai 3-20, Vorconditarife |
| EUR 79,56                 | Gebraucht - Sehr gut | Verkäufer: Herb Tandree Philosophy Books  
90% positiv in den letzten 12 Monaten. (236 Bewertungen insgesamt)  
Verkäuferinformationen, Impressum, AGB, Widerrufsrecht | Ankunft zwischen Mai 2-6, Versand aus Vereinigtes Königreich, Versandtarife |
### Customer Choice based on a given Market Situation

<table>
<thead>
<tr>
<th>seller</th>
<th>price</th>
<th>quality</th>
<th>rating</th>
<th>feedback</th>
<th>shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k )</td>
<td>( p_k )</td>
<td>( q_k )</td>
<td>( r_k )</td>
<td>( f_k )</td>
<td>( c_k )</td>
</tr>
<tr>
<td>1</td>
<td>44.90</td>
<td>akzeptabel</td>
<td>100%</td>
<td>4</td>
<td>5 Tage</td>
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<tr>
<td>2</td>
<td>45.00</td>
<td>sehr gut</td>
<td>98%</td>
<td>28,584</td>
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<td>3</td>
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<td>4</td>
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<td>90%</td>
<td>338</td>
<td>10 Tage</td>
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<tr>
<td>( \ldots )</td>
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<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
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</tr>
<tr>
<td>( K )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
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</tr>
</tbody>
</table>

*Data-Driven Demand Learning and Dynamic Pricing Strategies – Customer Behavior*
Goals of Today’s Meeting (Exercise I)

• Task: Understand & describe Customers’ Decisions over time

• Assume: A product with multiple features (price, quality, ratings)
  A list of competitors’ offers (market situation)
  Stream of interested customers + buying decisions

• Goal: Simulate arriving customer and their buying decision
  given a simulated set of competitors’ offers
(1) Stream of Arriving Customer

- Any ideas?

- Simulate random delays (waiting times) between two customers

- Use, e.g., Uniform distributions or Exponential distributions

- Is this doable?
(2) Merchants’ Offers & Market Situations

- Simulate offers, i.e., random numbers for prices, quality, ratings

<table>
<thead>
<tr>
<th>seller ( k )</th>
<th>price ( p_k )</th>
<th>quality ( q_k )</th>
<th>rating ( r_k )</th>
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</thead>
<tbody>
<tr>
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<td>akzeptabel (4)</td>
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<tr>
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</tr>
<tr>
<td>3</td>
<td>65.60</td>
<td>wie neu (1)</td>
<td>89%</td>
</tr>
<tr>
<td>4</td>
<td>79.56</td>
<td>sehr gut (2)</td>
<td>90%</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( K )</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
(3) Customers’ Decision

- Assume: A customer arrives at time $t$ – how does he/she decide?

- Approach I: Always choose the cheapest offer

- Approach II: Use distribution of sales and price rank

- Approach III: Use (randomized) scoring functions

- Other: Combinations, data-driven, etc.
Approach I: Cheapest Offer

- Idea: An interested customer always chooses the cheapest offer

- Easy / deterministic?

- In case of identical prices use probabilities:

\[
P(k, \bar{s}) = P(k, \bar{p}, \ldots) = \begin{cases} 
\frac{1}{\left\{ k = 1, \ldots, K : p_k = \min_{i=1,\ldots,K} p_i \right\}}, & k = 1, \ldots, K : p_k = \min_{i=1,\ldots,K} p_i \\
0, & k = 1, \ldots, K : p_k > \min_{i=1,\ldots,K} p_i
\end{cases}
\]
Approach II: Sales vs. Price Rank

- Idea: Relative frequency of sales and price ranks

- Example: 100 sales \( \rightarrow \) #60 rank 1, #30 rank 2, #10 rank 3, \ldots

  \[i.e., \ H \text{ sales} - h_1 = 60, \ h_2 = 30, \ h_3 = 10, \ldots\]

- Simulate the buying probability \( P(k, \bar{s}) \) that rank \( k \) is chosen, \( k = 1, \ldots, K \)

\[
P(k, \bar{s}) = P(k, \bar{p}, \ldots) = \frac{h_{\text{rank}(p_k, \bar{p})}}{\sum_{i=1,\ldots,K} h_i}
\]
Approach III: Randomized Scoring

- Idea: Different customers use different scoring functions

- Customer Type 1: \( \arg \min_{k=1,\ldots,K} \left\{ p_k + 0.1 \cdot q_k - 0.01 \cdot r_k - 0.01 \cdot f_k^{0.5} \right\} \)

- Customer Type 2: \( \arg \min_{k=1,\ldots,K} \left\{ p_k + 0.15 \cdot q_k - 0.005 \cdot r_k - 0.03 \cdot f_k^{0.5} \right\} \)

- Customer Type 3: \( \arg \min_{k=1,\ldots,K} \left\{ p_k + 0.2 \cdot q_k - 0.05 \cdot r_k - 0.02 \cdot f_k^{0.5} \right\} \)

\[ \ldots \]

- We can model the decision of a random customer as follows:

\[
\arg \min_{k=1,\ldots,K} \left\{ p_k + U(0,0.2) \cdot q_k - U(0,0.1) \cdot r_k - U(0,0.05) \cdot f_k^{0.5} \right\}
\]

Data-Driven Demand Learning and Dynamic Pricing Strategies – Customer Behavior
How to Simulate Customer Choice?

- We need: Realisations of (stochastic) buying behavior for various market situations in our models

- Approach I+II: “Inverse Verteilungsmethode for $P(k, \bar{s})$ via $U(0,1)$”

- Approach III: - simulate random scoring coefficients, e.g., $U(0,0.05)$
  - compute scores for all $K$ offers
  - choose the offer with the best score

- Do you think you can do this?
(4) Combination: Arriving and Buying Customers

- Assume a generated market situation
- Simulate arriving customers over time
- Simulate customers’ individual decisions
- Doable?
(5) Extensions: Changing Market Situations

- (i) Entry / Exit of firms

- (ii) Price adjustments

- Simulate streams of points in time of a merchant’s actions (‘arrivals’)

- Doable?
(6) Exercise II: Response Strategies

- Assume a merchant can place his/her action at time $t$

- Apply a rule-based price reaction strategy
  
  (i) Use a random price
  
  (ii) Undercut the cheapest competitor price
  
  (iii) Undercut others or raise the price if prices are too cheap

- Doable?
### Overview

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>April 24</td>
<td>Customer Behavior</td>
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<tr>
<td>April 30/1</td>
<td>Pricing Strategies, 1(^\text{st}) Homework (simple)</td>
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<td>Demand Estimation, 2(^\text{nd}) Homework (cont.)</td>
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<td>Warm up Platform Exercise (in Groups)</td>
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